SkyRepeater

A communication method successfully demonstrated using readily available amateur (ham) radio equipment with minor modifications, mounted on a tethered helium-filled balloon or high-lift kite to establish ad hoc two way radio communications in remote areas, radio dead zones and in the case of a repeater failure. Tested on both VHF and UHF bands, one person can setup in 15 minutes. Cost is approximately $2,000.00. Minimum wind requirement is approximately 6 mph for a kite. Maximum wind for tethered spherical helium balloon is approximately 20 mph.

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I. EXECUTIVE SUMMARY.

SkyRepeater is a communication method successfully demonstrated using readily available amateur (ham) radio equipment with minor modifications, mounted on a tethered helium-filled balloon or high-lift kite to establish ad hoc two way radio communications in remote areas, radio dead zones and in the case of a repeater failure. It has been tested on both VHF and UHF bands. One person can setup in 15 minutes. Minimum wind requirement for the kite is 6 mph.

The **r**adio **c**ommunications **n**etwork (RCN) is established using two **c**ross **b**and **r**epeat (CBR) radios lifted to altitude. Another method is to use one radio connected to what is called a digital simplex repeater. There are two main variations. Isolated RCN (iRCN) is where the network does not interact with the main repeater system of which there are two types, simplex and semi-duplex. Connected RCN (cRCN) is where the RCN does interact via radio frequency with the main repeater system. There are three variations on cRCN, depending upon requirements and the host system design.

II. ACKNOWLEDGMENTS.

Special thanks to George Cline (KP2G) for his invaluable ideas, advice and suggestions. Also thanks to Bob Schlesinger (NP2MM) and Selma Rockett (KG6SXJ) for helping with tests and for suggestions for this paper.

III. INTRODUCTION.

It was a dark and stormy night. The hurricane (earthquake/tsunami/terrorist) destroyed the repeater tower. Rescue, Search and Rescue, Police, Fire, EMS and cleanup are ongoing with emergency services responding in full force. Coordination is difficult because they cannot talk with each other because their radios were designed for use with repeaters.

SkyRepeater will help. Most emergency communications nationwide utilize repeaters. In lay terms, repeaters give radios much more range but the use of repeaters also means that the individual radios cannot communicate directly with each other (except in some circumstances over short distances) without the repeater to act as a translator, so to speak, or intermediary, between these radios. This is because the radios all transmit on one frequency, call it frequency A, and receive on a different frequency, call it frequency B. The repeater listens only to the radios' transmit frequency (in our example it is frequency A) and the repeater simultaneously retransmits on the radios' receive frequency (frequency B). If the repeater or the tower it is on is damaged, communications is lost. Please see the two diagrams from ARRL, attached as exhibits 1 & 2 on pages 13 & 14.

An ad hoc RCN is created by lifting a pair of CBR radios or digital simplex repeater(s) on a helium balloon or high-lift kite. The system is called SkyRepeater.

Lifting a full repeater is not practical because of weight and the need for large and heavy batteries. It is also not necessary because CBR radios, a time tested but largely forgotten technology, will do the same job a different way. Two CBRs are required because each one does half of what is needed. One will repeat, for example from VHF to UHF. The second will repeat back from UHF to VHF. The simplest version

of a SkyRepeater signal diagram, using 2 CBRs, is shown below, at Scenario A on page 6. Scenario B on page 7 demonstrates an even simpler, 'one- radio-with-digital-simplex-repeater' system.

Another way to conceptualize SkyRepeater is simply as a "range extender." It will extend the range of your department's normal communications. SkyRepeater will create an ad hoc radio network in remote areas and radio dead zones so emergency services can operate with their regular radios and without changing settings or channels. SkyRepeater will also be of value if the radio repeater or tower it is on were damaged.

Each emergency service (police, fire, EMS) must have its own SkyRepeater or have its radios programmed for a common or mutual frequency.

IV. BACKGROUND.

The concept of pairing two CBRs to make a "full repeater" does not appear to have been tried before. The concept of lifting a repeater on a small, weather or meteorological balloon or a kite also does not appear to have been tried before. Balloons and kites have been used to lift cameras and communications antennas, but not transmitting radios or repeaters.

The Naval Postgraduate School (Monterey, California) and the United States Special Operations Command are now experimenting with a much more sophisticated version of a similar idea, creating what they call "Ad Hoc Wireless Networks" to improve battlefield communications using WIFI technology. As platforms, they use airplanes, unmanned aerial vehicles, ships, satellites and balloons. Because of the limitations from too much wind, kites should also be considered as an option.

V. HELIUM BALLOON.

Achieving the necessary lift by using a helium balloon was the initial SkyRepeater idea but helium is temporarily not available in the US Virgin Islands. The cost of the helium necessary to fill a balloon capable of lifting three pounds would be approximately $180.00 in the VI and thus would prohibit frequent and regular tests of the system.

Also, high winds will blow a tethered balloon horizontal, reducing its effectiveness and making launch and recovery difficult if not dangerous. Low cost spherical weather balloons will start to lose effectiveness at wind speeds of 15-20 mph. (There is a balloon advertised as stable at 90 mph, called the Sky Doc. I have not tested it (see www.floatograph.com/oilspill/skydoc.html)).

VI. HIGH LIFT KITE.

Air is free and at least in the VI, there is almost always a 6 mph breeze. A 60 square foot surface area Flow Form HQ 60 kite was chosen because it does not have any frame or require any stays. Thus, it stores small and flat and there are no parts to break or disappear. Also, the kite is stable in unstable winds, is a good lifter, will withstand high gusts and at approximately 10 mph, will provide sufficient lift for SkyRepeater. I purchased a second kite called a Rokaku for lower wind.

VII. HEIGHT MATTERS.

Because VHF and UHF radio waves travel essentially in straight lines, transmit and receive radios must be able to "see" each other electronically. This is called "line of sight." Thus SkyRepeater needs to be lifted high enough to see all parties to the conversation with as few obstructions as possible. For the isolated networks, this could be just high enough above ground level to clear dense foliage and terrain irregularities. For the networks that must interact with the main repeater system, SkyRepeater must be lifted high enough to electronically see the main repeater.

Whether kites or balloons are used, the tether or rope has weight and eventually, whatever lift is created will be counteracted by the weight of the rope. An option would be to use a larger balloon or larger surface area kite. Both options will work yet could, in the right conditions, lift a human and result in injury. Also, bigger balloons require more helium and thus increase cost.

Another concern is aircraft. There is not much risk in SkyRepeater a few hundred feet off of the ground but there could be at higher altitudes. A solution to this could be to raise SkyRepeater from a mountain top. This might bridge the gap permitting SkyRepeater to see both the ad hoc RCN and the main repeater, yet the kite or balloon would be safely close to the ground, on the mountain top.

FAA regulations require notification of the nearest airport for any kite or balloon higher than 150 feet.

VIII. ANALYSIS AND RECOMMENDATIONS.

iRCN simplex is the least complicated SkyRepeater version because along with the digital simplex repeater, only one radio needs to be in the air and it does not have to be a CBR radio. An agency's usual duty radio could be used or any number of easily obtained and programmable ham radios. Ham radios must be modified to transmit beyond the strictures of the amateur radio band. This is called a MARS Mod (Military Affiliate Radio Service) and usually entails some unsoldering inside the radio).

iRCN semi-duplex will probably be the most common SkyRepeater use because some agencies may not have a preprogrammed simplex channel or a simplex switch (sometimes called Talk Around).

All of the cRCNs require that SkyRepeater be high enough to see the main repeater.

A series of tests with extensions to tested, theoretical and not-tested scenarios are discussed in this paper. They include: iRCN semi-duplex; iRCN simplex; cRCN semi-duplex with CBR; cRCN semi-duplex with four CBRs; and cRCN semi-duplex with dual simplex repeaters.

IX. EQUIPMENT USED AND SOURCES.

The Flow Form HQ 60 was purchased from Colors on the Wind, 118 E Wellesley, Spokane, WA 99207, 509-484-5483, 888-484-5483 (toll free), 509-484-8012 fax, http://www.colors-wind.com/ for approximately $240.00.

For low wind conditions, I used a Rokaku kite from http://www.shannonkites.com/contact.htm. This is a beautifully hand made kite better suited to low winds (4 mph) than the Flow Form, $350.00.

All equipment is suspended from a separate payload line, attached to the kite at the kite's main connection point where the kite line attaches to the kite. Please see photograph. Each radio is enclosed in a 10" X 20" waterproof gear bag made by WTex called the Pneumo Dry Sack 5, and available from REI for less than $20.00. The Pneumo attaches to the payload line with a carabineer on one end while the Pneumo's closure buckle encircles the payload rope for extra protection on the other end.

Nighttime visibility is enhanced by several ACR Electronics Inc., "C-Strobes." This is a 2 AA battery strobe designed for life vests and available from West Marine for approximately $30.00. Six of them dangle freely from the kite line at intermittent distances along the line with one more attached as close to the kite itself as possible The danglers show us where the line is. This one close to the kite lights it up with each strobe flash and creates a stunning nighttime display.

The ICOM W32A appears to be the only handheld radio that will do CBR (see photo). It is an excellent radio although complicated as any multi-function programmable amateur radio will be. It can be obtained from any ham radio equipment supplier such as AES Ham www.aesham.com, or Ham Radio Outlet www.hamradio.com. It can also be purchased directly from ICOM. With proper documentation, they will do the MARS mod (modifies the ham radio so it can transmit outside of the official FCC amateur radio bands) for you and this is a real help. http://www.icomamerica.com/products/amateur/w32a/. ICOM's phone number is (425) 454-8155. For government agencies, ask for GSA sales. Total cost should be less than $400.00 including MARS Mod, programming software and programming cable. Operating time is approximately 6 hours (only NiCad batteries are available) at approximately 50% duty cycle, so you may want to order extra batteries.

A simplex repeater is a battery operated digital voice recorder that gets plugged in to a radio. Sometimes they are referred to as "store and forward repeaters". They record the conversation and repeat it on the same frequency. I used the MFJ-664 available for $130.00 www.mfjenterprises.com (see photo). In addition, you will need to get connectors that fit whatever radio you want to use with the simplex repeater. For emergency communicators, I suggest a variety of cables for those unforeseen emergency needs.

X. PROOF OF CONCEPT –TWO CBR'S TOGETHER WILL SUCCESSFULLY ACT LIKE A FULL REPEATER.

March 8, 2005. Bob Schlesinger, NP2MM and Marty Alperen, NP2LW.

Two ICOM W32A handheld radios were used as CBRs. Each was put in to CBR with the frequencies as shown below. Two other radios (radio A & radio B) were used to test the system. Radios A & B were not adjusted from normal operating procedures thus they could not talk to each other without a repeater. It worked.

When the ICOMs were next to each other, there was a noticeable hum. At 8 feet of separation, there was none.

Radio A (Yaesu VX5R 5 W handheld)
Rx 158.750
Tx 153.910

CBR 1: Rx 153.910
TX 453.7875

CBR 2: Rx 453.7875
Tx 158.750

Radio B (Kenwood TMV7A 50 W mobile in truck)
Rx 158.750
Tx 153.910

TEST REPEATED, JULY 30, 2005, Selma Rockett, KG6SXJ and Marty Alperen NP2LW. VHF Rx 160.140, Tx 150.790, Yaesu VX5R and Vertex 180. (Notes: initially, both the Yaesu and the Vertex could transmit but only the Yaesu would receive. After programming the appropriate subaudible tone to CBR2, the Vertex received without any difficulty. Also, increasing output power to HI for CBR2 enabled a more distant station to receive the 5 watt ICOM.)

XI. Scenario A. Verified.

iRCN semi-duplex. The on the ground radios operate in semi-duplex as usual without making any settings changes and as if there was a repeater. No interaction with main repeater.

iRCN example signal path of a semi-duplex transmission from Radio A to Radio B (read top to bottom).

Radio A, on the ground, Tx on 150.790 (the radio's usual output which is the usual repeater input).

CBR 1
Rx 150.790
TX 453.7875 **LOW POWER**

SkyRepeater

CBR 2
RX 453.7875
Tx 160.1400 **HIGH POWER**

Radio B, on the ground, Rx on 160.140, (the radio's usual input which is the usual repeater output).

XII. Scenario B. Verified.

iRCN simplex. The on the ground radios operate in simplex. Only possible if the on the ground radios have a preprogrammed simplex frequency or a simplex switch (sometimes called Talk Around).

No interaction with main repeater.

iRCN example signal path of a simplex transmission from Radio A to Radio B (read top to bottom).

Radio A, on the ground, Tx on 158.750

SkyRepeater

One radio, does not need to be CBR, with attached simplex repeater.
Rx 158.750

Digitally recorded and retransmitted by simple repeater

Tx 158.750

Radio B, on the ground, Rx on 158.750

XIII. Scenario C. Theoretical.

cRCN semi-duplex with CBR. The on the ground radios operate in semi-duplex as usual without making any settings changes and as if there was a repeater. Requires that the main repeater system accommodate a cross band input and output. Used to extend range of an operating system.

cRCN example signal path of a transmission from Radio A to Radio B (read top to bottom).

Radio A, on the ground, Tx on 153.910 (the radio's usual output which is the usual repeater input).

CBR 1
Rx 153.910
TX 453.7875 to the main repeater system, its UHF input.

SkyRepeater

CBR 2
RX 453.550 from the main repeater, its UHF output.
Tx 158.750

Radio B, on the ground, Rx on 158.750, (the radio's usual input).

XIV. Scenario D. Theoretical.

cRCN semi-duplex with four CBRs. The on the ground radios operate in semi-duplex as usual without making any settings changes and as if there was a repeater. Requires two additional (total of 4) CBRs in the sky. Used to extend range of an operating system.

cRCN example signal path of a transmission from Radio A to Radio B (read top to bottom).

Radio A, on the ground, Tx on 153.910 (the radio's usual output which is the usual repeater input).

SkyRepeater

CBR 1
Rx 153.910
TX 453.7875 to CBR 2.

CBR 2
RX 453.7875
Tx 153.910 to Main Repeater.

CBR 3
Rx 158.750 from Main Repeater
Tx 458.4375

CBR 4
Rx 458.4375
Tx 158.750 to the ground radios.

Radio B, on the ground, Rx on 158.750.

XV. Scenario E. Theoretical.

cRCN semi-duplex with dual simplex repeaters. The on the ground radios operate in semi-duplex as usual without making any settings changes and as if there was a repeater. Used to extend range of an operating system.

cRCN example signal path of a transmission from Radio A to Radio B (read top to bottom).

Radio A, on the ground, Tx on 153.910 (the radio's usual output).

SkyRepeater

Radio 1, does not need to be CBR, with attached simplex repeater.
Rx 153.910

Digitally recorded and retransmitted by simplex repeater
TO THE MAIN REPEATER AT 153.910

MAIN REPEATER DOES ITS WORK AND SIMULTANEOUSLY RETRANSMITS ON 158.750.

Radio 2, does not need to be CBR, with attached simplex repeater.
RX 158.750 from the main repeater.

Digitally recorded and retransmitted by simplex repeater
TO THE GROUND.
Tx 158.750

Radio B, on the ground, Rx on 158.750, (the radio's usual input).

XVI. CONCLUSION.

For relatively little money any agency can have a truly transportable repeater that can be set up in a matter of minutes to permit communications in remote areas, radio dead zones and in the case of a repeater or tower failure.

Potential uses are limited only by our imagination. For example, put the simplex repeater or CBRs on a window sill on a hill overlooking a remote incident. Hang them from a tree, ladder or put them on an extension pole attached to your emergency vehicle.

SkyRepeater will also work with the more powerful mobile radios providing they have CBR capability. Imagine an emergency deep in a remote ravine with no communications. Position two vehicles with their mobile radios set to CBR near the edge.

XVII. GLOSSARY.

CBR: cross band repeat. This is a radio that simultaneously repeats a radio frequency but on a different band. For example, a VHF signal (153.910) is retransmitted as UHF (453.7875).

cRCN: Connected Radio Communication Network. A RCN that is connected to the agency's usual repeater.

Fx: frequency.

iRCN: Isolated Radio Communication Network. A RCN that is not connected to the agency's usual repeater.

RCN: Radio Communication Network. The network of radios connected via SkyRepeater.

Rx: A radio's receive frequency.

Tx: A radio's transmission frequency.

UHF: Ultra High Frequency. The name given to a range of frequencies in the 70 centimeter band or around 400 MHz.

VHF: Very High Frequency. The name given to a range of frequencies including the amateur frequencies in the two-meter band or around 144 – 148 MHz, as well as Marine and Business bands ranging from 144 – 172 MHz.

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Latex Balloons: Kaymont Consolidated Industries, 21 Sprucetree Lane, Huntington Sta., NY 11745, (631) 424-6459, www.kaymont.com

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1075 E. Bocock Rd, Marion Indiana, 765-664-6134, 9 A.M. to 5 P.M. EST,
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http://www.foreverflying.com/fightershannon.html

http://www.flexifoil.com/

D. CARIBINERS AND LINE:

Any Mountain, Berkeley, CA (510) 665-3939 www.anymountaingear.com

Marmot Mountain Works, Berkeley, CA (510) 849-0735

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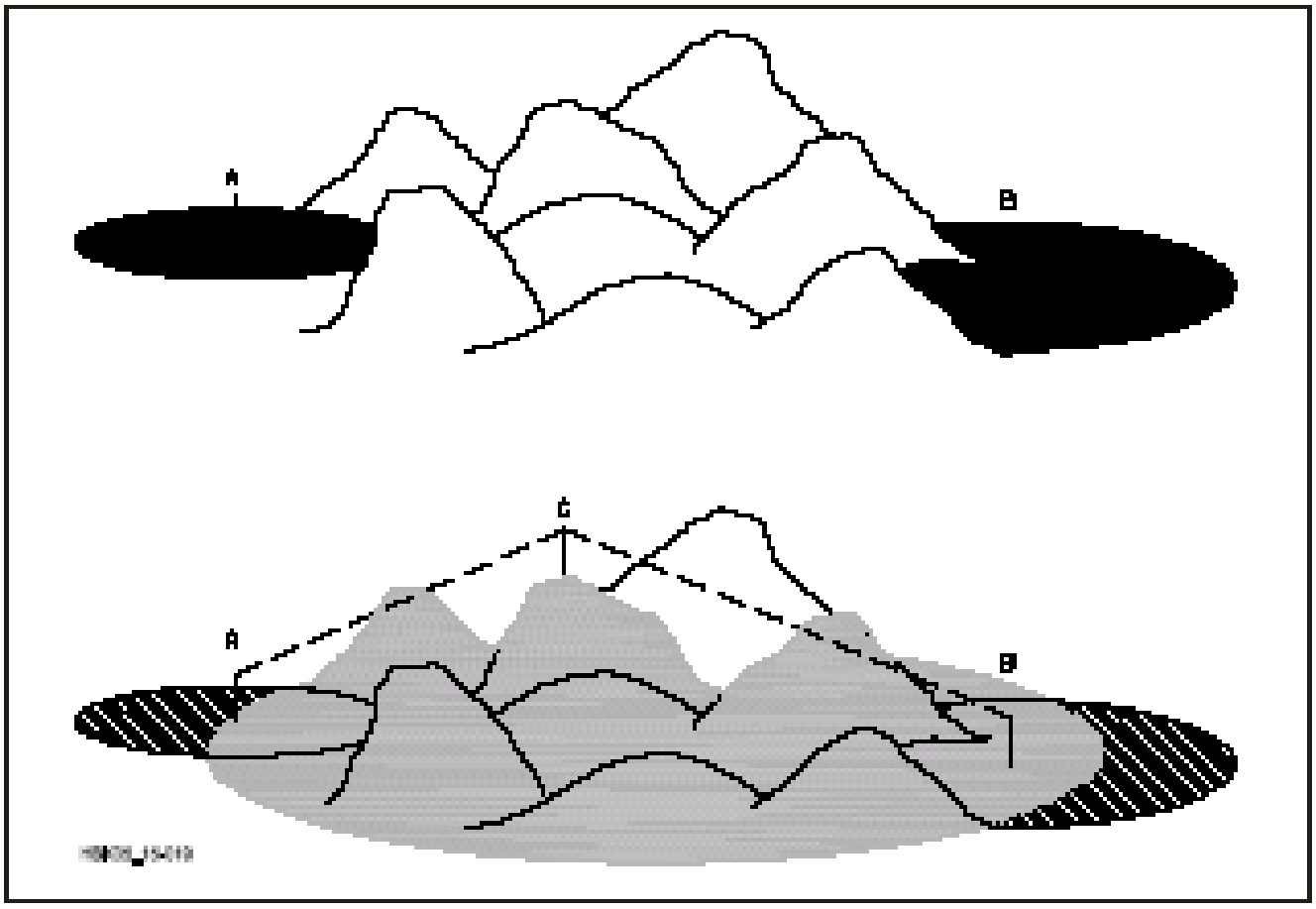

Fig 15.19 — In the upper diagram, stations A and B cannot communicate because their mutual coverage is limited by the mountains between them. In the lower diagram, stations A and B can communicate because the coverage of each station falls within the coverage of repeater C, which is on a mountaintop.

Figure 1, with permission from ARRL (Amateur Radio Relay League, www.arrl.org).

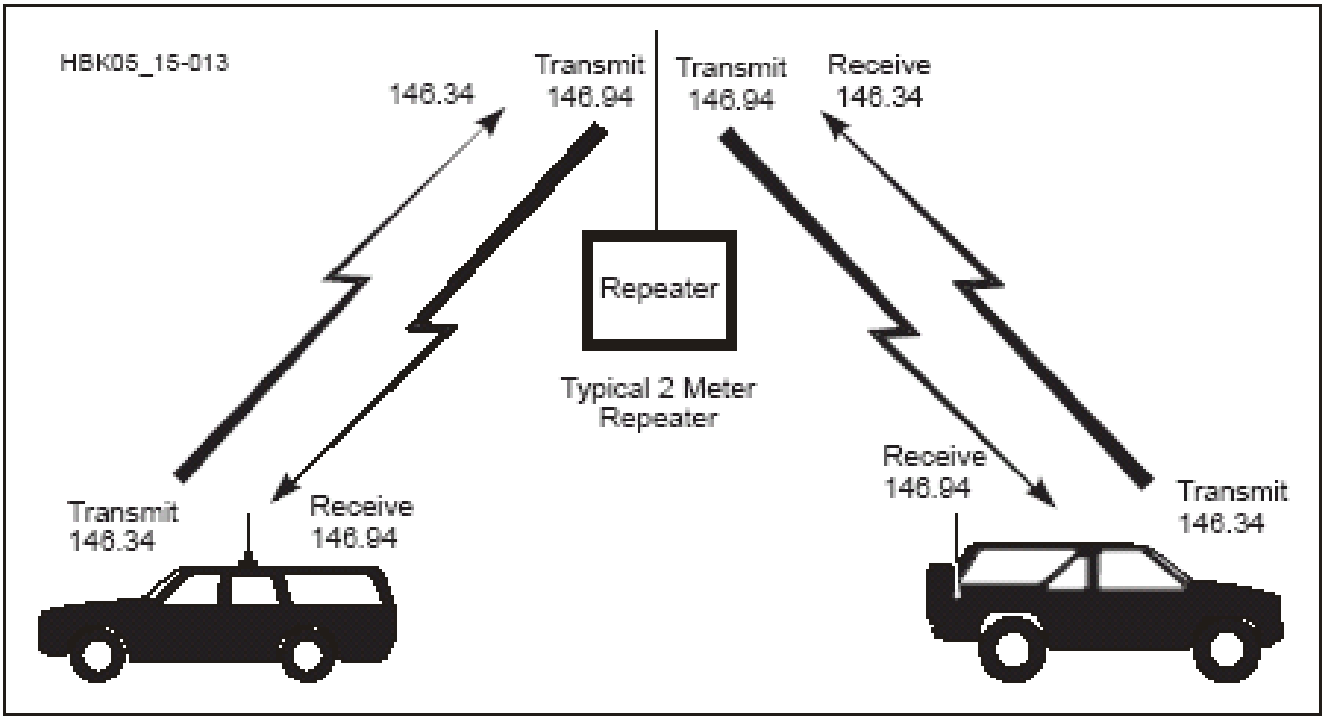

Fig 15.13 — Typical 2-m repeater, showing mobile-to-mobile communication through a repeater station. Usually located on a hill or tall building, the repeater amplifies and retransmits the received signal on a different frequency.

Figure 2, with permission from ARRL (Amateur Radio Relay League, www.arrl.org).